

Claims

1. Magnetic calibration device comprising:
 - a mounting means (15) designed to support at least one magnetic sensor card (17a) being detachably attached and comprising at least one magnetic sensor, in particular in form of a Hall sensor (23), to be calibrated and connected to a first analog electronic circuit with at least one current source (22) as well as at least one first analog to digital converter (20a) and at least one coil card (17) being detachably attached and comprising three coils (18) arranged substantially orthogonal to each other and connected to a second analog electronic circuit with at least one second analog to digital converter (20);
 - at least one connection means, in particular in form of a cable (21) or a wireless link, for applying at least one supply voltage V_s to the first and second analog electronic circuits, respectively, and for guiding digital signals from the first and second analog to digital converter (20a, 20), respectively, to at least one processing unit;
 - a magnet for generating a substantially homogeneous and constant calibration magnetic field; and
 - a rotator for rotating said cards (17a, 17) in said calibration magnetic field around two substantially orthogonal axes.
2. Magnetic calibration device according to claim 1, characterized in that the rotator comprises two conical gears (13, 14), such as tooth gears or roll gears, two substantially concentrically arranged shafts (6, 8) and at least one driving unit for the shafts, in particular in form of a stepper engine controller connected to two engines and/or connected to the shafts (6, 8) via worm wheels (7, 9).
3. Magnetic calibration device according to claim 2, characterized in that the at least one driving unit is arranged outside the calibration magnetic field.
4. Magnetic calibration device according to claim 2 or 3, characterized in that the speed and direction of rotation of the two shafts (6, 8) is controlled by the at least one driving unit to cover the full ranged of polar and azimuthal angles of the unit sphere by a continuous movement, preferably including a time reversed rotation for compensating induction effects in the at least one magnetic sensor (23).

5. Magnetic calibration device according to one of the claims 2 to 4, characterized in that the magnetic calibration device is at least partly formed by vibration damping and non-conducting material, preferably at least one of the shafts (6, 8) comprises heavy, non-conducting material and/or is arranged in slide bearings (11, 12).
6. Magnetic calibration device according to one of the claims 2 to 5, characterized in that the amount of turns of the inner shaft (8) differs from the amount of turns of the outer shaft (6) by one turn within one calibration cycle, the cable (21) being preferably turned only once within one calibration cycle.
7. Magnetic calibration device according to one of preceding claims, characterized in that the at least one processing unit is arranged outside the calibration magnetic field and stationary.
8. Magnetic calibration device according to one of the preceding claims, characterized in that
several magnetic sensor cards (17a) and/or at least one magnetic sensor card (17a) and the coil card (17) are stackable next to each other, preferably closely spaced apart.
9. Magnetic calibration device according to one of the preceding claims, characterized by at least one dowel pin, screw, plug, clamp and/or clip to precisely and reproducibly position at least one magnetic sensor card (17a) and/or coil card (17).
10. Magnetic calibration device according to one of the preceding claims, characterized in that
one magnetic sensor card (17a) carries one 3-dimensional or one 2-dimensional and one 1-dimensional or three 1-dimensional Hall sensor (s) (23).
11. Magnetic calibration device according to one of the preceding claims, characterized in that
the first analog electronic circuit comprises at least one low pass filter, multiplexer and/or delta-sigma modulator (20a).

12. Magnetic calibration device according to one of the preceding claims, characterized in that
the second analog electronic circuit comprises at least one low pass filter, multiplexer and/or delta-sigma modulator (20).
13. Magnetic calibration device according to one of the preceding claims, characterized in that
the first and/or second electronic circuit, in particular the at least one low pass filter, is arranged in the region of the center of rotation of the cards (17a, 17).
14. Magnetic calibration device according to one of the preceding claims, characterized in that
the process unit comprises:
 - means for integrating the digital coil signals to obtain the components of the calibration magnetic field in angular coordinates relative to the coils;
 - means for decomposing the digital magnetic sensor output voltages into spherical harmonics on the basis of the obtained angular coordinates; and
 - means for storing the obtained coefficients of the spherical harmonics as a function of the calibration magnetic field to obtain a calibration table.
15. Magnetic calibration device according to one of the preceding claims, characterized by at least one magnetometer, particular in at least one NMR magnetometer and/or fixed Hall sensor, arranged within the calibration magnetic field and connected to the processing unit to provide the absolute value of the calibration magnetic field to the processing unit.
16. Magnetic calibration device according to one of the preceding claims, characterized in that
the processing unit comprises:
 - means for performing a transformation of the obtained angular coordinates for aligning the reference frame with the symmetry axes of the at least one magnetic sensor.

17. Magnetic calibration device according to one of the preceding claims, characterized by at least one temperature sensing element, comprised by a thermistor or the Hall sensor and connected to the processing unit in order to supply the temperature within the calibration magnetic field, in particular of the Hall sensor, to the processing unit.
18. Magnetic calibration device according to claim 17, characterized in that the processing unit comprises:
 - means for obtaining the temperature of the Hall sensor by decomposing the Hall input voltages depending on the magnitude and direction of the calibration magnetic field and the temperature into spherical harmonics on the basis of the decomposition of the Hall output voltages.
19. Magnetic calibration device according to one of the preceding claims, characterized by a thermal insulating box housing the mounting means with the magnetic sensor and coil cards, said thermal insulating box preferably connected to a control circuit for controlling the temperature within the box measured in particular by the temperature sensing element.
20. Magnetic calibration device according to claim 19, characterized in that the control circuit, preferably comprised by the processing unit, comprises a Peltier element for cooling and/or heating, at least one ventilator, preferably driven by an engine outside the calibration magnetic field, and a controller.
21. Magnetic calibration device according to one of the preceding claims, characterized in that the current source of the Hall sensor is either a constant current source or a precise voltage source with an internal resistance substantially equal to the input resistance of the Hall sensor.
22. Magnetic calibration device according to one of the preceding claims, characterized in that at least two magnetic sensor cards are supported by the mounting means, one card carrying at least one calibrated Hall sensor and each remaining card carrying at least one Hall sensor to be calibrated by comparison with the at least one calibrated Hall sensor.

23. Magnetic calibration device according to one of the preceding claims, characterized in that
the processing unit is comprised by a microprocessor and/or personal computer.